

## Recent Results from BESIII

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In this talk, we will present some recent results on charmonium spectroscopy and hadron spectroscopy from BESIII experiment, including the measurements of the masses and widths of  $h_c$ ,  $\eta_c$ ,  $\eta_c(2S)$  and some new resonances around 2 GeV. The results are based on a data sample of 106 million  $\psi'$  events and 226 million  $J/\psi$  events collected with the BESIII detector at the BEPCII collider.

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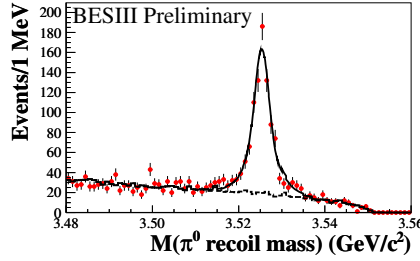
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## 1. Introduction

In this paper, some recent results from BESIII experiment on charmonium spectroscopy and hadron spectroscopy are presented based on about 106 million  $\psi'$  events and 226 million  $J/\psi$  events collected by the BESIII detector at the BEPCII collider.

## 2. Observation of $h_c$

Using the largest  $\psi'$  sample collected by the BESIII, we study the 16 specific decay processes of  $\eta_c$  in the decay chain of  $\psi' \rightarrow \pi^0 h_c$ ,  $h_c \rightarrow \gamma \eta_c$ . Figure 1 shows the  $\pi^0$  recoil-mass spectrum of the sum of the 16 decay modes. A simultaneous fit to the 16  $\pi^0$  recoil-mass spectra yields  $M(h_c) = 3525.31 \pm 0.11 \pm 0.15 \text{ MeV}/c^2$  and  $\Gamma(h_c) = 0.70 \pm 0.28 \pm 0.25 \text{ MeV}$ . These preliminary results are consistent with the previous BESIII inclusive measurement [1].



**Figure 1:** The summed  $\pi^0$  recoil-mass spectrum of 16 specific decay processes of  $\eta_c$  in the decay chain of  $\psi' \rightarrow \pi^0 h_c$ ,  $h_c \rightarrow \gamma \eta_c$ , where the line is the fit result.

## 3. Measurement of the $\eta_c$ properties

Based on the  $\psi'$  sample, the  $\eta_c$  mass and width are measured in the radiative transition  $\psi' \rightarrow \gamma \eta_c$ , where  $\eta_c$  are reconstructed from six decay modes:  $K_S^0 K \pi$ ,  $K^+ K^- \pi^0$ ,  $\pi^+ \pi^- \eta$ ,  $K_S^0 K 3\pi$ ,  $K^+ K^- \pi^+ \pi^- \pi^0$  and  $3(\pi^+ \pi^-)$ . A simultaneous fit with the unique  $\eta_c$  mass and width is performed on the  $\eta_c$  mass spectra, where the interference between  $\eta_c$  and non-resonance decays is considered and the quantum number of the non- $\eta_c$  components are assumed to be  $0^{-+}$ . Assuming an universal relative phase between the two amplitudes, we obtain  $\eta_c$  mass and width,  $M = 2984.2 \pm 0.6 \pm 0.5 \text{ MeV}/c^2$  and  $\Gamma = 31.4 \pm 1.2 \pm 0.6 \text{ MeV}$ , respectively, as well as the relative phase  $\phi = 2.41 \pm 0.06 \pm 0.04 \text{ rad}$ . Figure 2 shows the fit results in the six  $\eta_c$  decay modes.

## 4. Observation of the M1 transition $\psi' \rightarrow \gamma \eta_c(2S)$

BESIII observed the M1 transition  $\psi' \rightarrow \gamma \eta_c(2S)$  with the decay mode  $\eta_c(2S) \rightarrow K_S^0 K \pi$ . Figure 3 shows the preliminary result for the  $K_S^0 K \pi$  invariant mass distribution, here the three-constraints kinematic fit has been applied (the energy of the photon is allowed to be floating). With the width of  $\eta_c(2S)$  fixed to PDG value, we measure mass of  $\eta_c(2S)$  to be  $3638.5 \pm 2.3 \pm 1.0$

$\text{MeV}/c^2$  and the  $BR(\psi' \rightarrow \gamma\eta_c(2S)) \times BR(\eta_c(2S) \rightarrow K_S K^\pm \pi^\mp)$  to be  $(2.98 \pm 0.57 \pm 0.48) \times 10^{-6}$ . The statistical significance for the M1 transition  $\psi' \rightarrow \gamma\eta_c(2S)$  is more than  $6.0\sigma$ . Combining the result  $B(\eta_c(2S) \rightarrow K\bar{K}\pi) = (1.9 \pm 0.4 \pm 1.1)\%$  from BABAR [2], the M1 transition rate for  $\psi' \rightarrow \gamma\eta_c(2S)$  is derived as  $BR(\psi' \rightarrow \gamma\eta_c(2S)) = (4.7 \pm 0.9 \pm 3.0) \times 10^{-4}$ , which is consistent with the CLEO's upper limit [3].

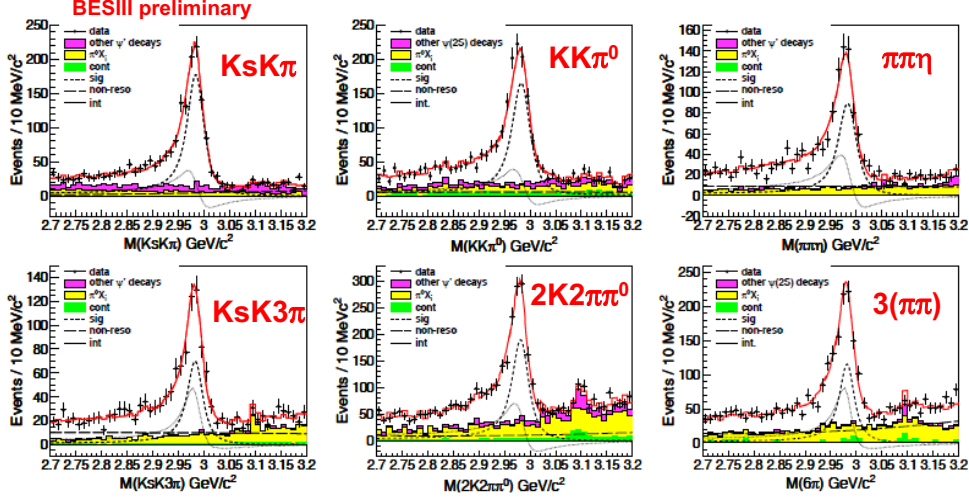


Figure 2: The mass spectra for different decay modes, where the line is the result of the simultaneous fit.

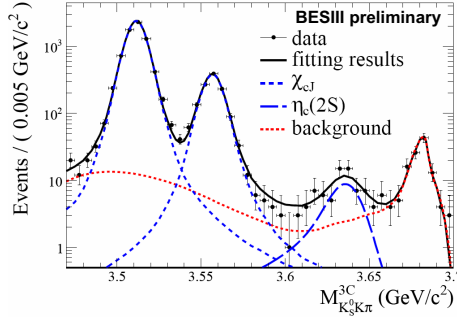


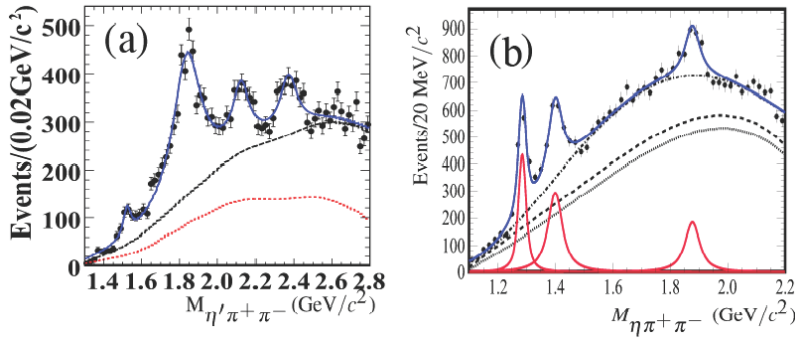
Figure 3: The invariant mass spectrum of  $K_S^0 K \pi$  from  $\psi' \rightarrow \gamma K_S^0 K \pi$ .

## 5. Observation of new resonances in $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$ and in $J/\psi \rightarrow \omega\eta\pi^+\pi^-$

The X(1835) was first observed in the  $J/\psi \rightarrow \gamma\eta'\pi^+\pi^-$  with statistical significance of  $7.7\sigma$  by the BESII experiment. A high statistical  $J/\psi$  data sample collected with the BESIII provides an opportunity to confirm the existence of the X(1835) and search for other new resonances. The  $\eta'\pi^+\pi^-$  invariant mass spectrum for the combined two  $\eta'$  decays,  $\eta' \rightarrow \gamma\rho$  and  $\eta' \rightarrow \pi^+\pi^-\eta$ , is presented in Figure 4(a). The X(1835) resonance is clearly seen. Additional peaks are observed around 2.1 and 2.3  $\text{GeV}/c^2$ , denoted as X(2120) and X(2370). The mass and width of X(1835)

are measured to be  $M = 1836.5 \pm 3.0^{+5.6}_{-2.1} \text{ MeV}/c^2$  and  $\Gamma = 190 \pm 9^{+38}_{-36} \text{ MeV}$  with significance larger than  $20\sigma$ . The mass and width for  $X(2120)$  ( $X(2370)$ ) are determined to be  $M = 2122.4 \pm 6.7^{+4.7}_{-2.7} \text{ MeV}/c^2$  ( $M = 2376.3 \pm 8.7^{+3.2}_{-4.3} \text{ MeV}/c^2$ ) and  $\Gamma = 83 \pm 16^{+31}_{-11} \text{ MeV}$  ( $\Gamma = 83 \pm 17^{+44}_{-6} \text{ MeV}$ ) with significance of  $7.2\sigma$  ( $6.4\sigma$ ). For more details, we refer to Ref. [4].

The decay  $J/\psi \rightarrow \omega \eta \pi^+ \pi^-$ , in which the  $\omega$  decays to  $\pi^+ \pi^- \pi^0$  and the  $\eta/\pi^0$  decays to a pair of photons, is studied to search for the  $X(1835)$ . The  $\eta \pi^+ \pi^-$  invariant mass spectrum with events in the  $a_0(980)$  mass window is shown in Figure 4 (b). Both  $f_1(1285)$  and  $\eta(1405)$  are observed significantly. A clear peak around 1900 MeV, denoted as  $X(1870)$  is also seen. A fit with three resonances with simple BW formula yields a mass  $M = 1877.3 \pm 6.3^{+3.4}_{-7.4} \text{ MeV}/c^2$  and a width  $\Gamma = 57 \pm 12^{+19}_{-4} \text{ MeV}$  for the  $X(1870)$  structure with statistical significance of  $7.2\sigma$ . More details on the data analysis can be found in Ref. [5].



**Figure 4:** (a) The  $\eta' \pi^+ \pi^-$  invariant mass distribution for the selected  $J/\psi \rightarrow \gamma \eta' \pi^+ \pi^-$  events from the two  $\eta'$  decay modes, (b) the  $\eta \pi^+ \pi^-$  invariant mass distribution for the selected  $J/\psi \rightarrow \omega \eta \pi^+ \pi^-$  events in  $a_0(980)$  mass window. Figures are taken from Refs. [4] and [5], and described there in more detail.

## 6. Summary and outlook

Some recent results on charmonium spectroscopy and hadron spectroscopy from BESIII experiment are shown based on a data sample of 106 million  $\psi'$  and about 226 million  $J/\psi$  events. In 2010 and 2011, BESIII have acquired nearly  $3 \text{ fb}^{-1}$  of data at the  $\psi(3770)$  resonance. This sample allows BESIII to begin the charm physics program, including the mixing and CP violation studies, as well measurements of absolute branching fractions and studies of semi-leptonic decays.

## References

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